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INVESTIGATION OF IMAGE CODING TECHNIQUES FOR TELEVISION TRANSMI--ETC(U)
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INVESTIGATION OF IMAGE CODING TECHNIQUES
FOR TELEVISION TRANSMISSION.

Contract No. N00123-75-C-1192/N

Submitted to
Naval Undersea Center
San Diego, California 92132

11 MAR 1976

10 Giner S. Robinson

Image Processing Institute
University of Southern California
Los Angeles, California

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1. Introduction

The Image Processing Institute of the University of Southern California initiated a research project on March 1, 1973 under contract N00123-73-C-1507 from the Naval Undersea Center to study various techniques of intraframe coding of video signals. On December 1, 1974 the Institute received another contract, N00123-75-C-1192, to extend the previously developed coding techniques to interframe coding of television signals. The objective of these projects was to develop efficient coding techniques of video signals from remotely piloted vehicles to ground stations.

In this final report, the results of the study on interframe coding will be summarized. The specific goals will be defined for improving and evaluating the performance of hybrid interframe coders on real-time RPV data.

2. Research Summary

The Image Processing Institute of the University of Southern California initiated a research project on March 1, 1973 under contract N00123-73-C-1507 from the Naval Undersea Center to study various schemes of intraframe coding of video signals. The object of the project was to develop an efficient technique of transmitting video signals from remotely piloted vehicles (RPV) to ground stations, compatible with rather severe power and volume restrictions on the transmitter.

The primary techniques that have been explored for intraframe coding are transform, linear predictive and hybrid transform/linear predictive techniques ~~(1,2)~~. The hybrid coding system which combines the attractive features of both transform and predictive coding systems has been studied in detail. The specific transform used is the discrete cosine transform ~~(3)~~. The hybrid cosine/DPCM system may be implemented to operate in real time through the use of charge coupled devices and conventional DPCM techniques ~~(4)~~.

In December 1974, the Image Processing Institute embarked on the second phase of the study, under a separate contract (N00123-75-C-1192) from the Naval Undersea Center, to study the interframe coding of RPV images and to extend the previously developed coding techniques to combine the spatial and temporal coding of image sequences. Coding systems based upon the two dimensional cosine and Fourier transforms combined with DPCM in temporal direction were investigated in detail. Results were presented in terms of coding

efficiency, storage requirements, computational complexity, and sensitivity to channel noise <5>. (Reference 5 is attached to this final report.) Performance of the hybrid interframe coders has been investigated in the presence of channel noise. Results show that, for both coder implementations studied, minimal image degradation occurred for a channel error probability of 10 or less.

A series of experiments were performed to determine the tradeoff between average bit rate per frame and the frame repetition rate for a fixed channel capacity. The measure of channel capacity used was the bit rate (BTR), which is defined as the product of average pixel bit rate per frame and frame rate. The results of these experiments show that reduced frame rates coupled with correspondingly higher average bit rates produce smaller MSE for the individual frames coded. This indicates that reductions experienced in frame-to-frame correlations due to temporal subsampling are completely compensated for by the increased number of bits available for coding. However, subjectively, reduced frame rates tend to result in jerky subject motion. In order to simulate this effect on actual RFV data, a new 64-frame 512 x 512 data base was digitized and coded using two-dimensional cosine combined with DPCM in temporal direction. This data base is of tactical significance since it represents a low altitude flyover of a chemical plant. Computer simulations performed on this data base have demonstrated high quality coded images with a 32:1 reduction in the average bit rate.

3. Outline of Future Studies

In this section, it is emphasized that further improvement of the hybrid two dimensional transform/DPCM interframe coder is possible. A performance evaluation should be undertaken to exercise the interframe coder using the real time RPV data base. This task requires in-depth investigations of the topics mentioned below.

3.1 Channel Noise and Error Detection/Correction

Simulations to evaluate the extent of image degradation due to the presence of channel noise have previously been reported for the hybrid two-dimensional transform/DPCM coders <5>. The generally monotonically non-decreasing character of the NMSE curves illustrates that, for the optimum implementation of the hybrid interframe coder, once an error occurs, its rate of decay is slow and the error tends to propagate in the temporal direction. From previous experience with intraframe hybrid transform/DPCM coders, it has been found that image degradations due to the inherent DPCM error propagation can be more rapidly reduced by using smaller than optimal weighting coefficients in the predictor feedback loop <6>. Thus, the predictor is operated in a manner which is suboptimal in the sense of minimizing the mean square prediction error. However, such operation has the advantage of accelerating the exponential decay in the contribution of transform coefficients of previously scanned pixels.

This concept can be applied to the hybrid interframe coder since a first order linear prediction is used to transmit transform

coefficient differences in the temporal domain.

It has been experimentally verified with hybrid intraframe coders that increases in image fidelity can be achieved by post processing of the encoded images to detect and then correct channel induced errors <7>. Prompt correction of errors detected at the receiver minimizes degradations to successive frames caused by error propagation.

The proposed detection of channel induced errors is a two step process. Initially, the assumption is made that differences between decoded transform coefficients for successive frames are small. Thus, a threshold approach is appropriate where the threshold is selected such that if the computed transform coefficient difference between successive frames exceeds this threshold, an error is considered likely. The second stage of the error detection process seeks to determine if an observed change which exceeded a given threshold is indeed an isolated error or is a valid leading edge of a local increase in decoded transform coefficient values. This determination is based on the exponential decay property which should occur during the several frames following the occurrence of an isolated error.

3.2 Bit Transfer Rate (BTR)

High quality RPV imagery in a Jammable environment depends in part on the frame rate employed. In many RPV missions such as navigation or general surveillance, the frame rate can be as low as 1 frame per second. For target acquisition, higher frame rates of 3 or 4 fps are considered adequate since this is the maximum rate at which

a human operator can assimilate new information. In the proposed simulations, BTR is defined as the product of average pixel bit rate per frame and frame rate and has units of bits/pixel/second:

$$\text{BTR} = (\text{bits/pixel/frame}) \times (\text{frames/sec})$$

For all cases examined with previous data bases it was shown that reduced frames coupled with correspondingly higher average bit rates result in smaller normalized MSE values for the individual frames coded. This indicates that reduction experienced in frame-to-frame correlations due to temporal subsampling are completely compensated for by the increased number of bits available for coding. However, subjectively, reduced frame rates tend to result in jerky subject motion. This is most apparent for rapidly moving objects in the field of view, and is of lesser consequence for slowly changing scenes. Intensive verification of this effect based on RPV imagery remains to be investigated.

3.3 Motion Compensation

A particular aspect of the RPV data base sequence is that it is generated from a moving platform. Consequently the images in the sequences exhibit frame-to-frame displacements in the spatial domain. Compensation for the effects of motion is a problem of great practical interest as frame-to-frame displacements reduces the correlation between pixels in sequential frames.

In general, moving areas in one frame of a television signal are very similar to corresponding areas in the previous frame except for a linear translation. Thus the effect of motion can be compensated if the speed and direction of motion can be estimated at the coder <8>.

Motion compensation using the discrete Fourier transform should be investigated for the hybrid two-dimensional transform/DPCM coder. The Fourier transform is considered because of its phase shift property; a shift in the spatial domain variables results in a multiplication of the Fourier transform of the un-shifted image by a phase factor. This shifting property is expected to be useful in detecting and compensating for effects of motion between frames since many types of motion such as panned motion produce significant changes in phase components and small changes in amplitude components. Thus, compensation for platform induced motion may be implemented directly in the array of phase components by application of appropriate phase correction factors.

3.4 Simplified Encoders

To achieve maximum coding performance, the hybrid two-dimensional transform/DPCM coder is designed to be adaptive in the sense that separate statistics and, consequently, separate bit allocations are computed for each subblock. An alternate version which features a much simpler implementation is a non-adaptive or simplified coder. Performance characteristics of the simplified coder should be compared with those of the adaptive coder. A series of simulations should be

performed using RRV data to determine degradations in coder performance resulting from non-adaptive implementations, e.g., use of average statistics for bit assignments, scaling and feedback loop coefficients and use of simplified quantizers. The objective of these simulations is the design of an interframe coder whose performance closely approximates that of the adaptive coder, but whose hardware implementation is considerably simplified. An additional topic which should be investigated is variations on subblock partition size used for two dimensional transforms.

4. References

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